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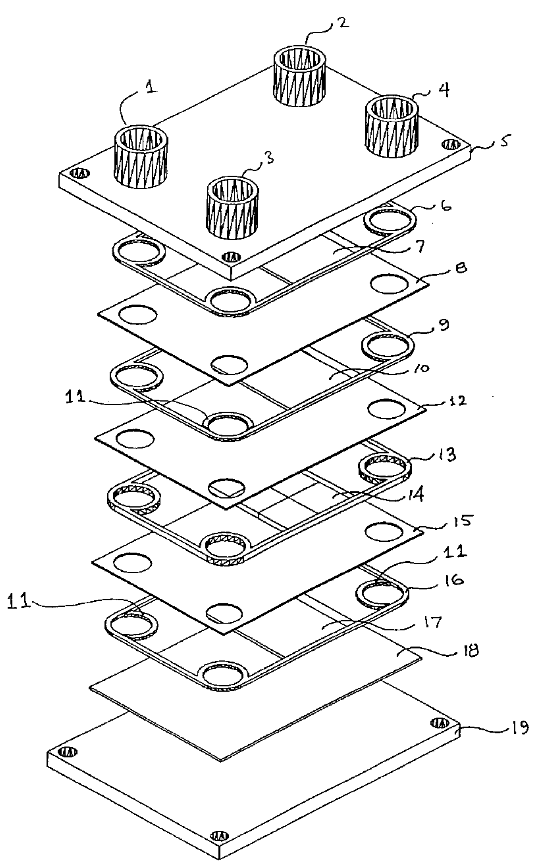
(54) Title: A HEAT TRANSFER APPARATUS



(57) Abstract: The invention relates to an apparatus comprising at least at first and a second flow channels of sandwich like structures for induction of a first and a second temperature, and a body of material, such as an electronic element, coupled there in-between. The sandwich like structures comprise two thermally conductive plates arranged in a parallel fashion, said plates having at least one open structure body arranged there in-between, thereby defining a passage for fluid flow and a passage allowing flow fo fluid through the interior. The flow of fluid is thereby directed through the open structure body, leading to respectively heating or cooling in the plates defining the body and thereby enhancing the efficiency of the apparatus.

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A HEAT TRANSFER APPARATUS

This application claims priority from Icelandic application No. 6280.

FIELD OF THE INVENTION

The present invention relates to an apparatus suitable for utilization of thermal energy flowing from a hot fluid to a colder fluid, such as in the generation of electricity. Alternatively, a similar device can be used as a heat pump where heat is transferred from one fluid to another by electronic means, or for other purposes in which a temperature gradient across a material provides useful changes in the physical properties of said material.

BACKGROUND OF THE INVENTION

Generation of electricity by means of the Seebeck/Thomson effect as well as cooling by the Peltier effect is usually accomplished by means of modules comprising an arrangement of crystals made of thermoelectric material where said modules have two opposite and parallel surfaces. For the purpose of generating electricity, one surface must be brought into thermal contact with a hot body and the other surface must be brought into contact with a cold body in order to induce flow of thermal energy from the hot body to the cold body through said thermoelectric module. As a consequence of the heat flow through the thermoelectric module, electromotive force arises across the ends of the thermoelectric crystals giving rise to electric current when connected through an electric load. Conversely, one surface of said thermoelectric module becomes colder and the other hotter than the immediate environment when electric voltage is applied across said crystals as utilized in a variety of cooling devices. Other physical principles that are applicable for the present invention involve a useful flow of electrons in response to heat flow, such as thermionic emission, and these principles also apply in the present invention.

A number of patents relate to the application of thermoelectric means for the purpose of cooling miscellaneous parts or fluids in a variety of embodiments but much fewer relate to the generation of electricity using thermoelectric or other electronic means. When the purpose of the apparatus is to transfer heat, or utilize heat transfer, between two fluids, the suggested embodiments often resemble traditional heat exchangers in their basic characteristics. Most employ an arrangement where two fluid flow channels, each having at least one flat surface, one channel with hot fluid and the other channel with relatively colder fluid, are brought into thermal contact on each side of a thermoelectric module with external pressure applied to the resulting stack to ensure good thermal contact between the heat transfer surfaces. In this arrangement, the following problems arise:

a) The externally applied pressure tends to collapse the fluid flow channels and deform the flat surface of the channel, and thus degrading the thermal contact that must be maintained between the flat surface of the channel and the electronic module. Embodiments have been introduced where this problem is solved by modifying the surface geometry of the inner walls of the channel such that mechanical support is provided through the channel against the external pressure applied, thus preventing deformation. The embodiments of the prior art achieve this mechanical support with complex and expensive assembly or machining operations, making the complete apparatus very expensive.

b) Due to the limited heat conductivity of the electronic modules, the fluid must flow slowly in the hot channel to be able to release the required heat through the electronic module into the cold fluid before the hot fluid exits the device. The same applies for the heat absorbtion of the cold fluid. Given the relevant heat transfer properties of water as the fluid and steel as the construction material of the flow channels in addition to the relatively poor thermal conductivity of the electronic module, the resulting flow velocity of the fluid is very low, giving rise to laminar flow and poor heat transfer from the fluid to the flow channel wall. Therefore, the embodiments of the prior art have attempted to increase the surface area of the inner walls of the flow channel by complex and expensive assembly or machining operations, making the complete apparatus very expensive.

Neither problem above is solved by corrugating the walls of the flow channel as is common in plate type heat exchangers as this leaves gaps in the contact with the thermoelectric module although the desired flow turbulence and mechanical support through the channel is accomplished. An improved heat transfer apparatus is therefore desirable that achieves good thermal contact as well as good heat transfer using inexpensive and simple materials and configurations.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a longitudinal cross section of one embodiment of an improved heat transfer apparatus of the present invention.

Figure 2 shows an exploded isometric view of the same embodiment as in Figure 1.

Figure 3 shows a cross section of an alternative embodiment of the present invention, in which only a single layer of electronic cells is accommodated.

SUMMARY OF THE INVENTION

According to the present invention, a heat transfer apparatus is provided, wherein said apparatus has the advantages of (i) providing even and efficient heat transfer; (ii) providing mechanical support within and between adjacent flow channels; (iii) being easily manufactured from available materials with minimal labour involved; (iv) being manufactured rapidly and inexpensively.

According to a first aspect of the present invention, an improved heat transfer apparatus is provided comprising:

- an enclosure comprising at least a top end plate and a bottom end plate with an interior for housing each of the following elements:
- at least a first flow channel for induction of a first temperature,
- at least a second flow channel for induction of a second temperature,
- at least one body of material coupled to said at least first and said at least second flow channels,

wherein at least one of said flow channels is a of sandwich-like layer structure comprising:

- at least two plates comprising openings for fluid flow, arranged in a substantially parallel fashion, wherein at least one of said plates is a thermally conductive plate.
- at least one open structure body arranged in-between said plates, thereby defining a channel for fluid flow,
- means for allowing fluid to flow through said channel thereby effecting heat transfer between said fluid and said thermally conducting plates,

wherein said first and said second flow channels are oriented in a substantially parallel fashion and wherein thermally conductive plates of said flow channels are positioned adjacently.

Such an apparatus can thereby maintain a temperature gradient across a layer of material, for example for the purpose of generating electricity, by means of fluids of different temperatures, in a simple and efficient apparatus or, alternatively, utilize a temperature gradient present in said layer of material for transfer of heat between said fluids.

According to one aspect of the invention, said openings may be substantially circular in shape. Further, in another aspect of the invention, said at least one body of material is comprised of electronic cells.

In one aspect of the invention, an apparatus as described above is provided, wherein at least one of said plates comprises one of said top end plate and bottom end plate.

In a further aspect, an apparatus is provided, wherein means for preventing fluid from escaping from said apparatus are provided. Such means may in one aspect be provided by resilient gaskets.

According to another aspect of the invention, a space is created between thermally conductive plates of adjacent fluid channels by means of a first resilient gasket, such that the at least one body of material may be accommodated. In a further aspect said space for said at least one open structure body may be provided by means of a second resilient gasket placed between said at least two thermally conducting plates.

In yet another aspect, said gaskets are provided in an outer part, substantially lining the outer edge of said thermally conductive plates, and an inner part substantially lining said openings. In one aspect, the outer and inner parts are provided in one continuous gasket.

In one aspect of the invention, said gaskets are provided by ducts of length substantially equal to the thickness of said body of material with means of sealing against fluid pressure and wherein said ducts are placed substantially concentrically with said openings. In a further aspect, strips of rigid material of thickness substantially equal to the thickness of said body of material are provided, wherein said strips are placed substantially at the outer edge of said plates.

In yet a further aspect of the present invention, the at least one open structure body is made of one or more materials selected from the group consisting of wire-mesh material, labyrinth of wires, ceramics, plastics, metals, sintered material and rigid foam material. Further, the at least one open structure body may be comprised of a plurality of non-open structure bodies, wherein said bodies are spatially oriented so as to generate turbulent fluid flow.

A further aspect of the invention provides a heat transfer apparatus comprising at least one open structure body placed substantially centrally within the opening between said plates and at least one open structure body placed in proximity of said openings.
In a further aspect of the present invention, said plates are stamped or machined for the purpose of securing in place said resilient gaskets or the at least one open structure body or the at least one body of material.

In another aspect a plurality of flow channel layers and layers comprising said at least one body of material are arranged alternately, thus forming a stack of any desired height. Further, in another aspect means of tightening said sandwich-like structure are provided. Said means may in suitable embodiments be provided by threaded rods and end-bolts.

According to yet another aspect, said plates are circular in shape, thus allowing circular gaskets to be used for fluid containment.

The present invention further provides a method of maintaining a temperature gradient across a body of material of substantially uniform thickness which comprises providing fluid flow through said first and said second flow channels of the apparatus of the invention, wherein said first flow channel is provided at a temperature different from the temperature of said second flow channel. According to the invention, said temperature gradient may be used to alter the physical properties of said material. In one aspect of the invention, said material induces electricity in response to the temperature gradient.

DESCRIPTION OF THE INVENTION

In the present context, a flow channel is a body which serves as a source and storage of thermal energy. Such a body, which can be considered to comprise a thermal reservoir body, may be used for the utilization of heat transfer from one thermal body to a second thermal body.

A body of material is in the present context considered to be any body of any material, which has useful characteristics when placed in a thermal gradient provided by the present invention. Such a body of material may in a useful embodiment be provided by an electronic cell.

An open structure body is in the present context considered to be a body with means for allowing liquid to flow through the body. Such an open structure body may be in the form of a porous material, or it may be comprised of a particular arrangement of otherwise liquid-impermeable material, which is arranged in a manner that allows liquid to pass through the body.

A thermally conductive plate is considered to be a plate comprised of material which conducts thermal energy. Such material is well known to those skilled in the art, and may for example be comprised of one or more metal, metal alloys or any other material showing properties of conducting thermal energy.

An electronic element is in the present context considered to be an element which can, upon exposure to differential temperature as in the case of a heat exchanger, give rise to electric current, based on principles well known to those skilled in the art.

In one embodiment of the present invention, each plate may be provided with four holes or openings near the corners as is common in plate heat exchangers and their purpose is substantially the same as in such heat exchangers. The open structure body, which may in preferred embodiments be comprised of at least one porous body, may be made of metal of uniform thickness, such as a wire mesh, which is placed within a gasket, covering the middle part of the plate such that fluid entering through holes at one end and exiting at the other end is forced through the open structure body, resulting in a flow across the width of the plate from one end to the other.

The open structure body serves multiple functions in the present invention, in that (1) it distributes the fluid entering through the nipples across the width of the flow channel; (2) it induces turbulent fluid flow in the space formed between the thermally conductive plates; and (3) it propagates compressive forces within the stack, so that compression is

overall uniform, thus ensuring a good seal between all elements of the apparatus, which is important for maximizing the efficiency of the apparatus.

Inducing turbulence in the fluid flow within the open structure body is important, as it prevents laminar flow within the fluid channel, and thus maximizes the efficiency of thermal energy flow and thereby contributes towards maximizing the efficiency of the apparatus.

The open structure further provides mechanical support to the overall structure. It defines and maintains a uniform gap between the thermally conducting plates. It further defines the thickness of the enclosing resilient gasket in the compressed state and propagates pressure exerted by the end plates through the stack.

A plurality of sandwiches is created, for the hot and cold fluid, alternately, in as great a number as desired. Between every two sandwiches, a layer of bodies of material is placed within the area covered by the open structure body in the flow channel. The bodies of material placed within this area may be of a variety of types, each one providing alternative embodiments of the present invention.

In one useful embodiment, the bodies of material are comprised of electronic cells, which are cells which, when accommodated in the apparatus according to the present invention, can be used to generate electricity. Other types of bodies with alternate responses to thermal energy gradients can be used in alternative embodiments of the invention.

After assembly of the stack of layers as described above, said top and bottom end plates, are placed at the top and bottom of the stack and tightened together with threaded rods or equivalent means. Upon tightening, the resilient gaskets compress until all the thermally conductive plates, the open structure body and the bodies of material come into mechanical contact, thus taking up all additional mechanical stress exerted on the stack by tightening the rods further.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Figure 1 shows a longitudinal cross section of an improved electronic heat transfer apparatus according to the present invention, in which electronic cells comprise the bodies of material placed between the fluid channels. Figure 2 shows an exploded isometric view of the same. Figure 3 shows a cross section of an alternative embodiment. The construction of the apparatus is in a number of ways similar to the construction of conventional plate heat exchangers with special features to accommodate bodies of material which utilize the thermal energy transfer provided by the apparatus, such as

electronic elements. Such bodies of material are commonly constructed with two parallel and flat surfaces through which heat is transferred.

A plurality of thermally conductive plates (8,12,15,18), made of conductive material, preferably a metal or an alloy, is shown. Further, a plurality of resilient gaskets (6,9,13,16), or other equivalent means for preventing fluid from escaping from the apparatus is shown. Further, a plurality of open structure bodies, which may in specific embodiments be comprised of porous bodies, of substantially uniform thickness (7,10,11,17) is shown. Further, two end plates (5,19), which are preferably stiff are shown, the first plate (5) having four nipples (1,2,3,4), two of which (3,4) are shown in Fig. 1, the second plate (19) having no nipple.

By alternating said thermally conductive plates (8,12,15,18) and said gaskets (6,9,13,16) in a stack as shown, with said first end plate (5) at top and said second end plate (19) at bottom, a first flow channel can be formed that directs hot fluid flow from a first nipple (3), through porous bodies (11,10) into a second nipple (4). A second flow channel for a cold fluid can be formed by an arrangement similar to said first flow channel where said cold fluid enters through a first nipple (1), then flows through porous bodies (11,17) and exits through a second nipple (2).

The open structure bodies (11) located near the holes in the thermally conductive plates (8,12,15) are of substantially uniform thickness, said thickness being substantially equal to the thickness of the larger open structured bodies found in the same layer, said open structure bodies (11) having the main purpose of providing mechanical support against pressures exerted by the resilient gasket (13) while at the same time allowing fluid to flow onwards to the larger open structure bodies in the same layer.

In assembly of the apparatus in one embodiment of the present invention, the parts are stacked up in alignment as shown in the exploded view in Fig. 2. By having the resilient gaskets thicker than the bodies they enclose, i.e. electronic cells and open structure bodies, said gaskets will compress when bolts (20) are tightened until the thermally conductive plates (8,12,15,18), the end plates (5,19), the open structure bodies (7,10,17) and electronic cells (14) are all in contact, such that further tightening of the bolts (20) will result in compression of said bodies to the level desired for good thermal conductivity. The thickness and stiffness of the resilient gaskets (6,9,13,16) must be controlled such that the final height of the stack causes sufficient surface pressure to hold the internal fluid pressures. The relative compression and stiffness of each type of resilient gasket (6,19,16) and (13), respectively, will tend to preserve the flatness of the thermally conductive plates (8,12,15,18).

A number of alternative embodiments exists for the various parts of the open structure body of the present invention. For example, the open structure bodies (7,10,11,17) may

be a wire mesh that allows flow transversally through its web while providing support of uniform thickness at every nodal point in the mesh where two wires cross. The wire mesh distributes the flow largely evenly across the width of the flow channel and introduces turbulence that enhances heat transfer.

Alternatively, the open structure bodies may comprise a labyrinth, or similar arrangement, of one or more wires of substantially uniform diameter, that direct the fluid flow in a pattern that induces suitable flow velocities or turbulence. With the wires lying flat on the adjacent thermally conductive plate, their uniform diameter ensures uniform thickness of the open structure bodies thus constructed.

Alternatively, the open structure bodies may comprise a slice of commonly available open structure materials, such as sintered metals, ceramics or plastics, or foams of the same materials. Alternatively, each open structure body as presented in the figures may comprise a plurality of various open structure bodies for the purpose of modifying flow patterns.

Each open structure body may alternatively be comprised of a plurality of non-open structure bodies, relatively densely spaced, said bodies having the purpose of modifying the flow pattern in the channel, thus generating turbulent fluid flow, as well as maintaining uniform gap between the adjacent thermally conductive plates under pressure.

The particular open structure body (7) in which no fluid flows needs not be of an open structure but is conveniently made of the same material and cut to the same dimensions as the open structure bodies 10 and 17. The purpose of said body (7) is to define the thickness of its enclosing resilient gasket in the compressed state and propagate pressure exerted by the stiff end plates (5,19) through the stack.

The end plates are preferably made of material of high mechanical stiffness. Such material may be comprised of a thermally conductive material; alternatively, the end plates are comprised of thermally insulating or half-conducting material, such as plastic or other polymers. In principle however, any material which provides necessary mechanical stiffness can be used.

The resilient gasket of the first type (13) serves the dual purpose of containing flow that is distributed to the flow channels and matching the surface pressure exerted on the thermally conductive plates (12,15) by the thinner resilient gaskets (9,16), so as to preserve the flatness of said thermally conductive plates. Alternatively, each of the four round parts of the resilient gasket of the first type (13) may comprise a duct of length equal to the thickness of the electronic cells (14) suitably sealed against the thermally conductive plates (12,15) with an o-ring or other equivalent means. The straight segments of the resilient gasket of thicker type (13) may alternatively be made of any

substantially rigid material of thickness equal to the thickness of the electronic cells (14) and preferably of low thermal conductivity.

The resilient gaskets may alternatively be laid out in other shapes that serve the same function as presented, including additional members to enhance separation between the thermally conducting plates.

The thermally conductive plates (8,12,15,18) may alternatively be stamped or machined in a shape that constrains movement of the resilient gaskets.

The entire assembly can be extended easily by repeating the layers comprising bodies 9,10,11,12,13,14 and 15 in such a way that hot and cold flow channels are formed alternately with bodies of material, such as electronic cells, in contact with two adjacent channels.

In Figure 3, an alternative embodiment of the present invention is described. This particular embodiment represents a simplified embodiment suitable when a single layer of electronic cells is accommodated. Further, this embodiment can be made in a relatively inexpensive and efficient manner. In this embodiment, two stiff end plates of principally identical design (23) replace the two end plates (5) and (19), each of the plates (23) having a first nipple (1,3) for fluid inlet and a second nipple (2,4) for fluid outlet.

The stiff end plates may be comprised of thermally conducting material; in principle however, any suitable stiff material may be used.

A stack of elements, comprising a first open structure body (10), a first thermally conductive plate (12), a suitable number of electronic cells (14), a second thermally conductive plate (15), and a second open structure body (17), is clamped between said stiff end plates (23). In said stack, thermally conductive plates are circular in shape, matching a ring (21) that encompasses said stack. To prevent fluid from escaping from water channels formed by said stack, seals such as o-rings (22) are placed at the outer rim of each of the first and second thermally conductive plates, lining said rims and enclosing each of the first and second porous bodies.

It should be understood that alternative embodiments of the present invention as described herein are possible, and that the examples provided herein should only be understood as representative and in no way limiting for the overall scope of the present invention.

CLAIMS

1. A heat transfer apparatus comprising:

- an enclosure comprising at least a top end plate and a bottom end plate with an interior for housing each of the following elements:

- at least a first flow channel for induction of a first temperature,

- at least a second flow channel for induction of a second temperature,

- at least one body of material coupled to said at least first and said at least second flow channel,

wherein at least one of said flow channels is of a sandwich-like layer structure comprising:

- at least two plates comprising openings for fluid flow, arranged in a substantially parallel fashion, wherein at least one of said plates is a thermally conductive plate.

- at least one open structure body arranged in-between said plates, thereby defining a channel for fluid flow,

- means for allowing fluid to flow through said channel thereby effecting heat transfer between said fluid and said plates,

wherein said first and said second flow channels are oriented in a substantially parallel fashion and wherein thermally conductive plates of said flow channels are positioned adjacently.

2. An apparatus according to claim 1, wherein said body of material is comprised of electronic cells.

3. An apparatus according to claim 1, wherein at least one of said plates comprises one of said top end plate and bottom end plate.

4. An apparatus according to claim 1, wherein means for preventing fluid from escaping from said apparatus are provided.

5. An apparatus according to claim 4, wherein said means are provided by resilient gaskets.

6. A heat transfer apparatus according to any of the preceding claims, wherein a space is created between thermally conductive plates of adjacent flow channels by means of a first resilient gasket.

7. A heat transfer apparatus according to any of the preceding claims, wherein space for said at least one open structure body is provided by means of a second resilient gasket placed between said at least two thermally conducting plates.

8. A heat transfer apparatus according to claims 5- 7, wherein said gaskets are provided in an outer part, substantially lining the outer edge of said thermally conductive plates, and an inner part substantially lining said openings.

9. A heat transfer apparatus according to claim 8, wherein said outer and inner parts are provided in one continuous gasket.

10. A heat transfer apparatus according to claim 6, wherein said gaskets are provided by ducts of length substantially equal to the thickness of said body of material with means of sealing against fluid pressure and wherein said ducts are placed substantially concentrically with said openings.

11. A heat transfer apparatus according to claim 10, further comprising strips of rigid material of thickness substantially equal to the thickness of said body of material, and wherein said strips are placed substantially at the outer edge of said plates.

12. A heat transfer apparatus according to claim 1, wherein the at least one open structure body is made of one or more materials selected from the group consisting of wire-mesh material, labyrinth of wires, ceramics, plastics, metals, sintered material and rigid foam material.

13. A heat transfer apparatus according to claim 1, wherein the at least one open structure body is comprised of a plurality of non-open structure bodies, wherein said bodies are spatially oriented so as to generate turbulent fluid flow.

14. A heat transfer apparatus according to claim 1, comprising at least one open structure body placed substantially centrally within the opening between said plates and at least one open structure body placed in proximity of said openings.

15. A heat transfer apparatus according to claim 1, wherein said plates are stamped or machined for the purpose of securing in place said resilient gaskets or the at least one open structure body or the at least one body of material.

16. A heat transfer apparatus according to claim 1, wherein a plurality of flow channel layers and layers comprising said at least one body of material are arranged alternately, thus forming a stack of any desired height.

17. A heat transfer apparatus according to claim 1, wherein said plates are circular in shape, thus allowing circular gaskets such as o-rings to be used for fluid containment.

18. A method of maintaining a temperature gradient across a body of material of substantially uniform thickness comprising providing fluid flow through a heat transfer apparatus comprising:

- an enclosure comprising at least a top end plate and a bottom end plate with an interior for housing each of the following elements:
- at least a first flow channel for induction of a first temperature,
- at least a second flow channel for induction of a second temperature,
- at least one body of material coupled to said at least first and said at least second flow channel,

wherein at least one of said flow channels is a of sandwich-like layer structure comprising:

- at least two plates comprising openings for fluid flow, arranged in a substantially parallel fashion, wherein at least one of said plates is a thermally conductive plate.
- at least one open structure body arranged in-between said plates, thereby defining a channel for fluid flow,
- means for allowing fluid to flow through said channel thereby effecting heat transfer between said fluid and said plates.

wherein said first and said second flow channels are oriented in a substantially parallel fashion and wherein thermally conductive plates of said flow channels are positioned adjacently, and wherein said first flow channel is provided at a temperature different from the temperature of said second flow channel.

19. The method according to claim 18, whereby said temperature gradient results in an alteration in the physical properties of said body of material.

20. The method according to claim 18, whereby said temperature gradient induces electricity in said body of material.

21. The method according to claim 18, wherein said body of material is an electronic cell.

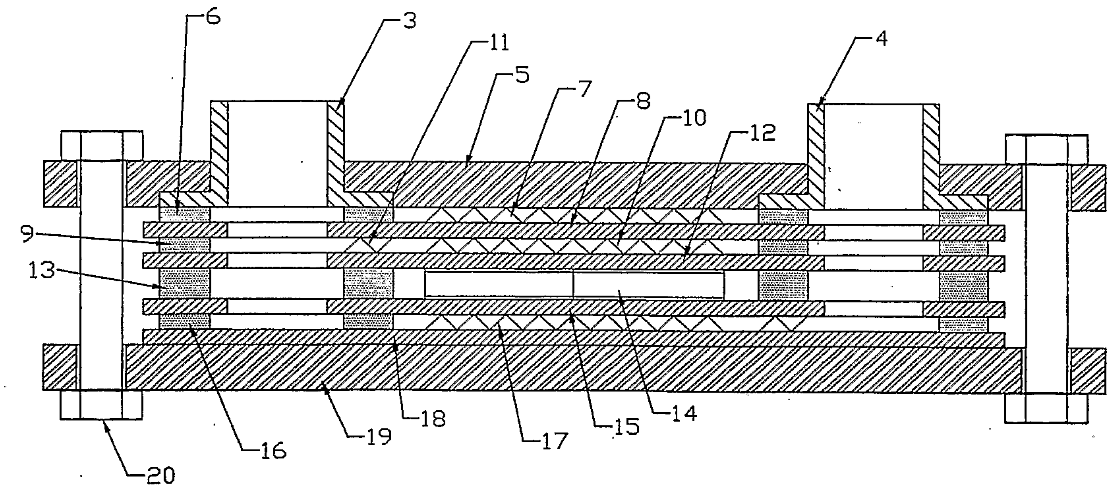

Fig. 1

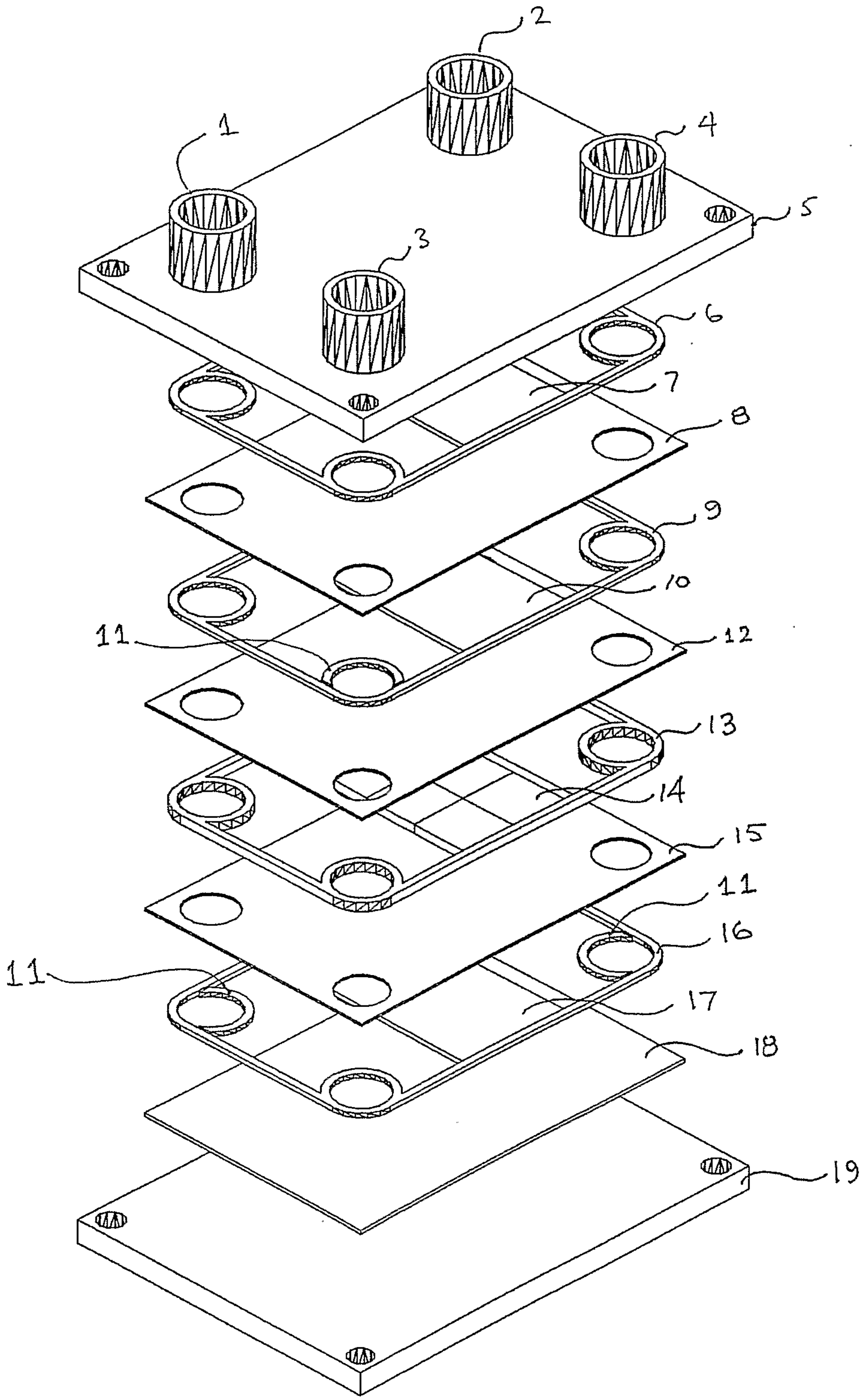

FIG 2

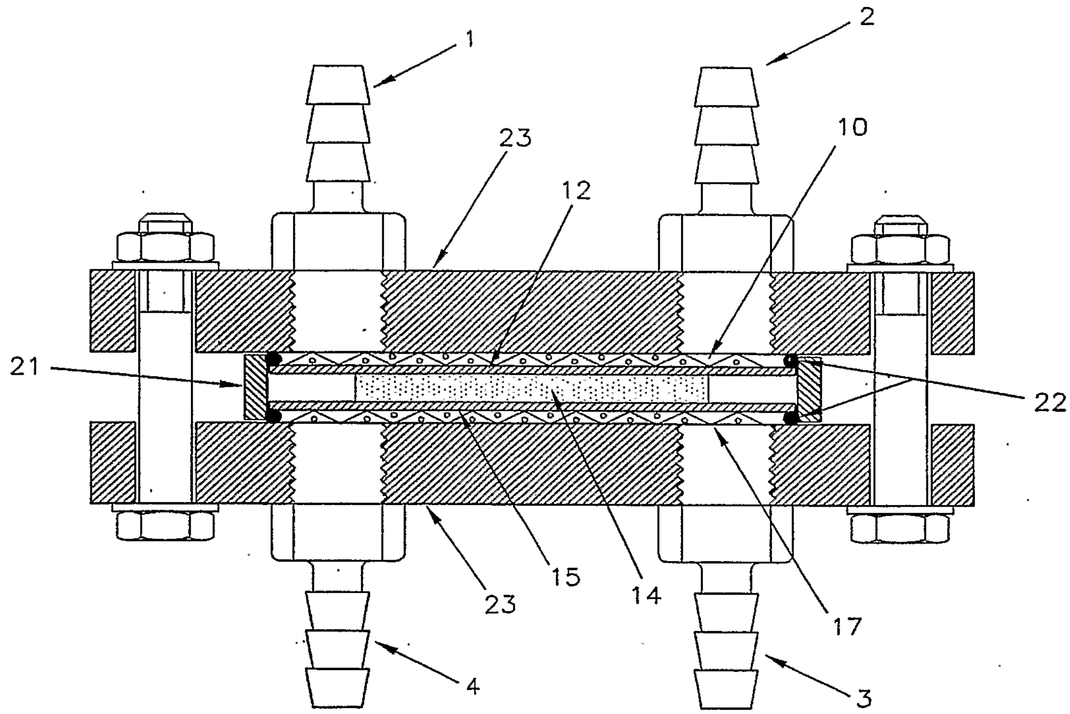

Fig. 3

INTERNATIONAL SEARCH REPORT

Internat pplication No
PCT/IS 03/00007

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F25B21/02 H01L23/38 H01L23/473 H05K7/20 F28D15/00
H02N11/00 H02N10/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F25B H01L H05K F28D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 02 086980 A (TOP COOL HOLDING B V ;ZELISSEN DANIEL ARNOLDUS MARIA (NL); ZELISSE) 31 October 2002 (2002-10-31) the whole document	1-21

X	US 5 584 183 A (WRIGHT LLOYD F ET AL) 17 December 1996 (1996-12-17)	1-5, 12-14, 16-18
	figures abstract	
A		6-11,15, 19-21

A	US 6 236 810 B1 (KADOTANI KANICHI) 22 May 2001 (2001-05-22) the whole document	1-21

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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